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**3. RECIPIENT'S CATALOG No.**

**4. TITLE AND SUBTITLE**

Compare In-Situ Strength of Asphalt Concrete Base (ACB) to Cement Treated Base (CTB)

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**7. AUTHOR(S)**

Weitzenberg, Richard W.; Buchey, Roy W.; Matthews, James A.; and Sherman, George B.

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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

**16. ABSTRACT**

This report presents the results of plate bearing tests and deflection measurements comparing the relative in-place strengths of cement treated base (CTB) and asphalt concrete base (ACB). This research was performed to develop a K-value design chart for ACB to supplement the K-value design chart for CTB that is now in use in the California Highway Design Manual. Plate beating tests were conducted on both ACB and CTB on highway project 05-Mon-1-R80.9/R85.0, and in the in-situ K-values were compared with each other and with the current K-value design chart for CTB. The research utilized the ASTM Standard Plate Bearing Test. Based on the plate bearing tests, it was found that the K-value of ACB is approximately 12 percent lower than the K-value of an equal thickness of CTB, where both are on the same foundation materials. Deflection measurements were obtained with the Benkelman beam, the California Traveling Deflectometer, and the Dynaflect on several projects to compare in-situ strengths of various thicknesses of ACB and CTB.

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DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY
RESEARCH REPORT

# Compare In-situ Strength of Asphalt Concrete Base to Cement Treated Base

74-17



FINAL REPORT
CA-DOT-TL-3110-1-74-17
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Prepared in Cooperation with the U.S. Department of Transportation,
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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY

December 1974

FHWA No. D-5-40
TL No. 633110

Mr. R. J. Datel
Chief Engineer

Dear Sir:

I have reviewed and now submit for your information this final research project report titled:

COMPARE IN-SITU STRENGTH OF ASPHALT CONCRETE BASE (ACB) TO CEMENT TREATED BASE (CTB)

Study made by . . . . . . . . . . . . . . . . Pavement Section

Under the Supervision of . . . . . . . . . . George B. Sherman

Principal Investigator . . . . . . . . . . . James A. Matthews

Co-Investigators . . . . . . . . . . . . . . Roy W. Bushey and Richard W. Weitzenberg

Assisted by . . . . . . . . . . . . . . . . Donald V. Roberts and Stephen C. Allen

Very truly yours,

JOHN L. BEATON
Chief Engineer, Transportation Laboratory

Attachment

ACKNOWLEDGMENTS

The authors wish to acknowledge the cooperation of Mr. Frank A. Avilla, Resident Engineer on project 05-Mon-1-R80.9/R85.0, Mr. George A. Ellis, Resident Engineer on project 03-Pla-80-18.8/22.9, and Mr. Edward Hayes, Resident Engineer on project 06-Tul-99-41.2/48.3.

Mr. Leigh S. Spickelmire and Mr. Paul I. Wagner of the California Division of Highways, Headquarters Construction and Design Branches respectively, served as advisors on this project. Mr. Billy F. Neal, Highway Engineering Associate, Transportation Laboratory, also acted as an advisor on this project.

The authors also wish to acknowledge the efforts of the men of the District 10 Equipment Shop, Stockton, under the direction of Mr. Marvin W. Hamlet and Mr. Albert B. Clark, for their assistance in providing equipment and emergency repair service to the vehicles used in the testing phase of the study.

Laboratory personnel involved with this study include Mr. Stephen C. Allen and Mr. Wesley N. Dwyer, both of whom were involved in all phases of the field testing. Assistance was also obtained at various times during the life of the project from Messrs. Gean D. McKindsey, David H. Johnson, Earl A. Boerger, Sylvester A. Dalske, Harvey D. Sterner, and James A. Quist. The Department of the Army, Sacramento District, Corps of Engineers, deserves a word of thanks for making available their plate bearing trailer unit and accessories to the laboratory for use during the field tests.

The research work reported herein was accomplished under Highway Planning and Research Project D-5-40 in cooperation with the U. S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the California Transportation Laboratory which is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

# INTRODUCTION

Current California design practice for most freeways and other major highways in the California State Highway System involves the design of a structural section consisting of a layer of subbase material, a layer of cement treated base (CTB), and a layer of portland cement concrete (PCC). A K-value design procedure is presently used to determine the PCC thickness requirement over CTB. The purpose of this research is to provide K-values for an asphalt concrete base which can be used in the portland cement concrete design procedure.

In the past few years, several construction projects on multi-lane, divided roadways have been constructed utilizing portions of the lanes in one direction as a construction detour while the opposite lanes are built. To facilitate this, either an asphalt concrete (AC) layer has been placed over the CTB to carry the detour traffic prior to placement of the PCC, or, in a few instances, AC has been used as a base material (ACB) in lieu of CTB. This research study develops a design chart for ACB similar to that used for CTB.

This report presents an evaluation of the performance of ACB where it has been used in the past, and the findings of an in-situ strength evaluation comparison between ACB and CTB. The report recommends an ACB design chart for use as an alternate to the CTB design chart now in use in California's Highway Design Manual [1].

This report also represents a follow-up study to two previous reports by the California Division of Highways, Materials and Research Department Report No. M&R 643449, "K-Value-Deflection Relationship for AC Pavements", dated November, 1969 [2], and Report No. 12 of the Highway Research Record Number 239, "A Thickness Design Method for Concrete Pavements", by A. C. Estep and P. I. Wagner, dated 1968 [3].

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## CONCLUSIONS

1. Plate bearing tests performed in this study indicate the K-value for asphalt concrete base is approximately 12 percent lower than the K-value for an equal thickness of cement treated base.

2. K-values and pavement deflections obtained on two asphalt concrete base projects are in agreement with the K-value vs. Deflection Curve published in Research Report No. M&R 643449[2].

3. A review of several projects constructed in the past indicates that PCC pavement constructed over ACB performs as well as PCC pavement constructed over CTB.

## RECOMMENDATIONS AND IMPLEMENTATION

1. The design chart, "Effect of Various Thicknesses of Asphalt Concrete Bases on K-Values", Figure 6, is recommended for inclusion in the California Highway Design Manual for use in the design of new PCC pavements over ACB.

2. The correlation curve "K-Value vs. Deflection for AC Pavements", Figure 7, published in research report No. M&R 643449[2], is recommended for utilization when designing PCC overlays placed on existing AC pavements.

## EVALUATION PROCEDURE

To evaluate the comparative strengths of ACB and CTB, it was proposed to analyze deflections and plate bearing tests on equal thicknesses of ACB and CTB placed over similar subbases. Considerable difficulty was experienced in locating highway projects where both ACB and CTB were to be placed, especially in equal thicknesses. In addition, the contractor's construction schedules did not permit the CTB to be exposed for 28 days.

Three highway projects were involved in the deflection analysis, project 05-Mon-1-R80.9/R85.0, project 03-Pla-80-18.8/22.9, and project 11-SD-805,395-18.2/21.4, 5.9/7.8. Plate bearing tests were conducted on both ACB and CTB on project 05-Mon-1, and on ACB on project 06-Tul-99. Cores were taken from three projects, 05-Mon-1-R80.9/R85.0, 06-Tul-99-41.2/48.3, and 06-Mad-99-18.5/22.5, for conducting laboratory tests on ACB and CTB of various ages.

A major requirement of this study was that of uniform basement and base materials beneath both the ACB and the CTB. On project 05-Mon-1, the AB was placed on compacted dune sand, the dune sand being of uniform size and quality throughout the entire project. On project 11-S-805,395, the structural section below the ACB and the CTB was the same. On project 03-Pla-80, the ACB and CTB test sections were located end to end within a cut section, and both were placed on 1.0 ft (0.30 m) Class 2 AB.

During March of 1973, a test section was constructed on 05-Mon-1 by a contract change order for the purpose of conducting the plate bearing tests needed for this research study. The base materials placed were a plant-mixed Class A CTB and a Type A asphalt concrete with a maximum aggregate size of 3/4 in (1.9 cm). The test area layout is diagramed in Figure 1. The California Traveling Deflectometer, an automatic Benkelman beam deflection measuring device, was used to lay out the test area by painting on the test surfaces the locations where the deflection readings were taken, a spacing of 18 to 20 feet (5.5 to 6.1 m) in both wheel tracks. Marking of the surface allowed us to obtain deflection readings at approximately the same location each time the readings were made. Deflectometer readings were taken on the CTB 7, 14, and 21 days after placement, and on the ACB at 4 and 11 days. Another deflection measuring device called the Dynaflect was used to obtain dynamic deflection values on the CTB at 7, 14, 21 and 27 days, and on the ACB at 10 and 16 days. Tests were performed on this project during April when the daily daytime temperatures ranged from 55° to 70°F (13 to 21°C).

All plate bearing tests were performed according to ASTM D1196-64, "Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, For Use in Evaluation and Design of Airport and Highway Pavements". The K-values were computed and corrected for bending of the plates in accordance with MIL-STD-621A, Method 104[4].

The plate bearing tests were conducted utilizing as a reaction force a heavy duty trailer, leased from the Sacramento District, U. S. Army Corps of Engineers, and loaded with water tanks and snow plow bits to a gross weight of approximately 52,000 pounds (23,600 kg), Figure 2. A hydraulic jack was used in conjunction with a load cell for applying and recording the load on the plates. The movement of the plates was recorded from three dial gages at each increment of load. This test arrangement is shown in Figure 3. All test locations were loaded to a deflection of 0.10+ inch (2.5 mm) or a maximum loading of 47,000 pounds (21,300 kg), whichever came first.

## DATA COLLECTION AND ANALYSIS

On project 05-Mon-1, twelve test locations were selected on in-place CTB and ACB to determine K-values for the two types of base materials. Plate bearing tests on CTB were performed at 7, 13, 14, 19 and 20 days after placement whereas plate bearing tests on ACB were made 8 days after placement. Contract work scheduling prevented plate bearing tests on 28 day CTB. The material underlying the ACB and CTB was tested by digging a 40-inch (1.02 m) diameter hole in the ACB and performing plate bearing tests on the aggregate base (AB).

Even though equal thicknesses of CTB and ACB were planned for this project, cores taken revealed the average thickness of ACB was 0.26 ft (7.9 cm) whereas the average thickness of CTB was 0.44 ft (13.4 cm). Due to this thickness difference, a direct K-value comparison could not be made between the ACB and CTB. The average K-value for the aggregate base was 363 psi/in. $\left[98.5 \frac{MN/m^2}{m} (MPa/m)\right]$.

To obtain an approximate 28 day K-value for the in-place CTB, K-values determined from the 7 to 20 day plate bearing tests were plotted against time and a 28 day value was projected (Figure 4). To check the reasonableness of this value, Figure 5, Effect of Various Thicknesses of Cement Treated Bases on K-values, was used to obtain a K-value for 0.44 ft (13.4 cm) CTB over a subbase with a K-value of 363 psi/in. (98.5 MPa/m). The projected K-value, 688 psi/in. (187 MPa/m) and the K-value determined from Figure 5, 680 psi/in. (185 MPa/m) are in good agreement.

To obtain a K-value correlation between ACB and CTB, the average K-value for ACB, determined from plate bearing tests, was compared to the K-value obtained from Figure 5 for 0.26 ft (7.9 cm) of CTB over a subbase with a K-value of 363 psi/in. (98.5 MPa/m). The K-values were 432 psi/in. (117 MPa/m) and 488 psi/in. (132 MPa/m) respectively. Thus $\left(\frac{488-432}{488}\right) \times 100 \approx 12$. From this, it was concluded that ACB has a K-value approximately 12 percent lower than that of an equal thickness of CTB. Based on these findings, an ACB design chart was developed (Figure 6). These design curves should be conservative since the ACB had a tendency to push up around the plates as discussed later in this report. A more uniform loading would result when placed under PCC. Also, this ACB was quite fresh when tested and would develop more slab strength as the asphalt hardens.

Transient deflections were obtained with either the Dynaflect, the Traveling Deflectometer, or the Benkelman beam on three projects, 03-Pla-80, 05-Mon-1, and 11-SD-805,395. The deflections obtained were nearly the same for equal planned thicknesses of ACB and CTB on these projects, indicating approximately equal strengths for the ACB and CTB placed on similar base materials (Table 2). All deflection data are reported in terms of the Benkelman beam.

On project 06-Tul-99, a plate bearing test was conducted on the existing AC highway surface prior to its being overlaid with PCC. The K-value was determined to be approximately 800 psi/in. (217 MPa/m) and the Benkelman beam deflection was 0.008 in. (0.20 mm). This compares quite well with the expected K-value of 850 psi/in. (231 MPa/m) determined from Figure 7, which was published in a previous study[2]. For project 05-Mon-1 the average deflection measurement and K-value on ACB were 0.028 in. (0.71 mm) and 432 psi/in. (117 MPa/m) respectively. This coordinate is in good agreement with the curve in Figure 7.

Research study number D-3-32, "Pavement Faulting Study", presently underway at the Transportation Laboratory, has involved several projects constructed on asphalt treated bases or subbases. Projects constructed on ACB include the following:

02-Sha-5-R19.0/R23.0

02-Sha-5-40.0/44.0, SBL

06-Ker-99-0.0/20.6

06-Ker-99-36.5/R43.4

*06-Mad-99-18.5/22.5, NBL

*06-Tul-99-41.2/48.3, NBL

07-LA-101-27.3/31.4

07-Ora-91-3.7/9.6

09-Ker-56-82.0/87.0, WBL

11-SD-163-3.7/7.0

*Indicates projects involved in testing for this research study.

Thirteen ACB cores and six CTB cores were obtained on projects 05-Mon-1, 06-Tul-99, and 06-Mad-99, for purposes of comparing surface abrasion and Abson recovery test results. The laboratory test results are given in Table 2. The cores exhibited good to excellent bond to the PCC. There was no apparent erosion of the ACB. The Abson recovery results show that the older ACB has lower penetration, ductility, and a higher softening point than the new ACB, which is to be expected. However, it must be kept in mind that the ACB on projects 06-Mad-99 and 06-Tul-99 had been used for many years as an AC pavement prior to its being overlaid with PCC. Therefore, the penetration, softening point, and ductility values of these old pavements are not necessarily indicative of what may be expected from ACB used as a wearing surface for a short time during the construction period before being overlaid with PCC.

The surface abrasion test results indicate that the ACB undergoes relatively uniform and minor decreases in its abrasion resistance with respect to time. They also indicate that ACB is less resistant to abrasion than CTB. This is important in cases where slab curling has led to pumping because the higher abrasion resistance of the AC should produce less fines attracted from the base to be contributed to pumping action.

Bituminous treatment was used to stabilize native base materials prior to PCC paving on several projects constructed in the late 1940's and early 1950's.

Projects constructed included:

03-Pla-80-17.2/19.0

03-Sac-160-45.0/46.5

05-SB-101-40.9/47.2

08-SBd-10-6.1/11.1

A research report titled "Faulting of PCC Pavements Constructed on Bituminous-Treated and Cement-Treated Subgrades", dated September 1, 1960[5], indicates that BTS is not quite as strong as CTS, which is comparable to our findings between ACB and CTB. Several of the projects constructed on BTS are still in service. Cores taen from these projects in conjunction with the Pavement Faulting Study reveal that the BTS is well bonded to the PCC, and that there is little evidence of stripping of asphalt from the aggregate, which is also consistent with our findings for ACB.

An attempt was made to correlate K-values with volumetric deflection basin by both Dynaflect and 18 inch (0.46 m) diameter plate bearing tests. See Figure 8 for the results of the Dynaflect measurements. The volumetric plate bearing tests were conducted with dial gages placed on the 18 inch (0.46 m) plate and on the testing surface 2, 4, 6, 8, and 10 feet from the center of loading. The readings on CTB indicated that the material was deflecting as a slab having a bowl shaped deflection basin. The ACB readings indicated the material was deflecting more by punching action than slab action. The punching was visually noticeable at a distance of approximately 15 inches (0.38 m) from the center of loading, and the dial readings indicated that underlying materials were being pushed up beyond 4 ft (1.2 m) from the center of loading.

The volumetric methods are felt to be unsatisfactory for comparison of ACB and CTB because of the difference in the way the two materials distribute the imposed loads, and because the inherent inaccuracy of the testing procedures can greatly distort the volumetric determination. For example, a difference of 0.001 in. (0.025 mm) in settlement between the 8 ft (2.4 m) and 10 ft (3.0 m) gages produces a volumetric difference of 0.002 $ft^3$ (57 $cm^3$), whereas a 0.001 in. (0.025 mm) difference between the 0 and 2 ft (0.6m) gages produces a volumetric difference of 0.0003 $ft^3$ (8.5 $cm^3$). Since the very small differential movements observed at greater distances from the center of loading, generally 0.001 in. to 0.002 in. (0.025 to 0.051 mm), have such a large impact on the final volume when compared to the impact the same differential movement has when obtained at the center of loading, the inaccuracies of the tests caused by temperature, wind, reading of the dial gages, etc., greatly distorts the volumes obtained.

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1. State of California, Department of Public Works, Division of Highways, "Portland Cement Concrete Pavement (7-605)", Highway Design Manual, Sacramento, California.

2. Hannon, J. B., Tueller, D. O., and Zube, E., "K-Value - Deflection Relationship for AC Pavements", Highway Research Report No. M&R 643449, State of California, Division of Highways, Materials and Research Department, Final Report, November, 1969.

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5. Tremper, B., and Spellman, D. L., "Faulting of PCC Pavements Constructed on Bituminous-Treated and Cement-Treated Subgrades", State of California, Division of Highways, Materials and Research Department, Preliminary Report, September, 1960.

TABLE I

K-VALUE DATA ON PROJECT 05-MON-1

Asphalt Concrete Base

| Test Number (See Figure 3) | Thickness (Feet) | K-Value (psi/in.) | Corrected K-Value* (psi/in.) |
|---|---|---|---|
| A1 | 0.25 | 483 | 385 |
| A2 | 0.27 | 538 | 415 |
| A3 | 0.27 | 565 | 440 |
| A4 | 0.23 | 446 | 360 |
| A5 | 0.27 | 606 | 455 |
| A6 | 0.27 | 714 | 520 |
| A7 | 0.27 | 599 | 450 |
| Average | 0.26 | 564 | 432 |

Aggregate Base

| Test Number (See Figure 3) | Thickness (Feet) | K-Value (psi/in.) | Corrected K-Value* (psi/in.) |
|---|---|---|---|
| B1 | 0.28 | 476 | 380 |
| B2 | 0.24 | 461 | 370 |
| B3 | 0.24 | 408 | 340 |
| B4 | 0.27 | - - | - - |
| Average | 0.26 | 448 | 363 |

Cement Treated Base

| Test Number (See Figure 3) | Thickness (Feet) | Age (Days) | K-Value (psi/in.) | Corrected K-Value* (psi/in.) |
|---|---|---|---|---|
| C1 | 0.46 | 7 | 442 | 360 |
| C2 | 0.43 | 7 | 286 | 265 |
| C1 | 0.46 | 13 | 971 | 650 |
| C2 | 0.43 | 13 | 678 | 500 |
| C3 | 0.53 | 14 | 476 | 380 |
| C4 | 0.39 | 14 | 833 | 575 |
| C1 | 0.46 | 19 | 862 | 590 |
| C2 | 0.43 | 19 | 1000 | 660 |
| C3 | 0.53 | 20 | 741 | 525 |
| C4 | 0.39 | 20 | 769 | 545 |
| C5 | 0.41 | 20 | 741 | 525 |
| Average | 0.44 | | | |

*Corrected for plate bending.

Note: 1 in. = 25.4 mm
1 ft = 0.305 m
1 psi/in. = 271 kPa/m

TABLE II

DEFLECTION MEASUREMENTS ON ACB AND CTB OVER SIMILAR SUBBASES

| PROJECT | ACB SECTION | | CTB SECTION | |
|---|---|---|---|---|
| | Average Thickness of ACB | Average Deflection Measurement | Average Thickness of CTB | Average Deflection Measurement |
| 05-Mon-1-R80.9/R85.0 | 0.26 ft | 0.028 in. | 0.44 ft | 0.022 in. |
| 11-SD-805,395-18.2/21.4, 5.9/7.8 | 0.45 ft | 0.018 in. | 0.45 ft | 0.019 in. |
| 03-Pla-80-22.8/27.4 | 0.80 ft | 0.006 in. | 0.80 ft | 0.004 in. |

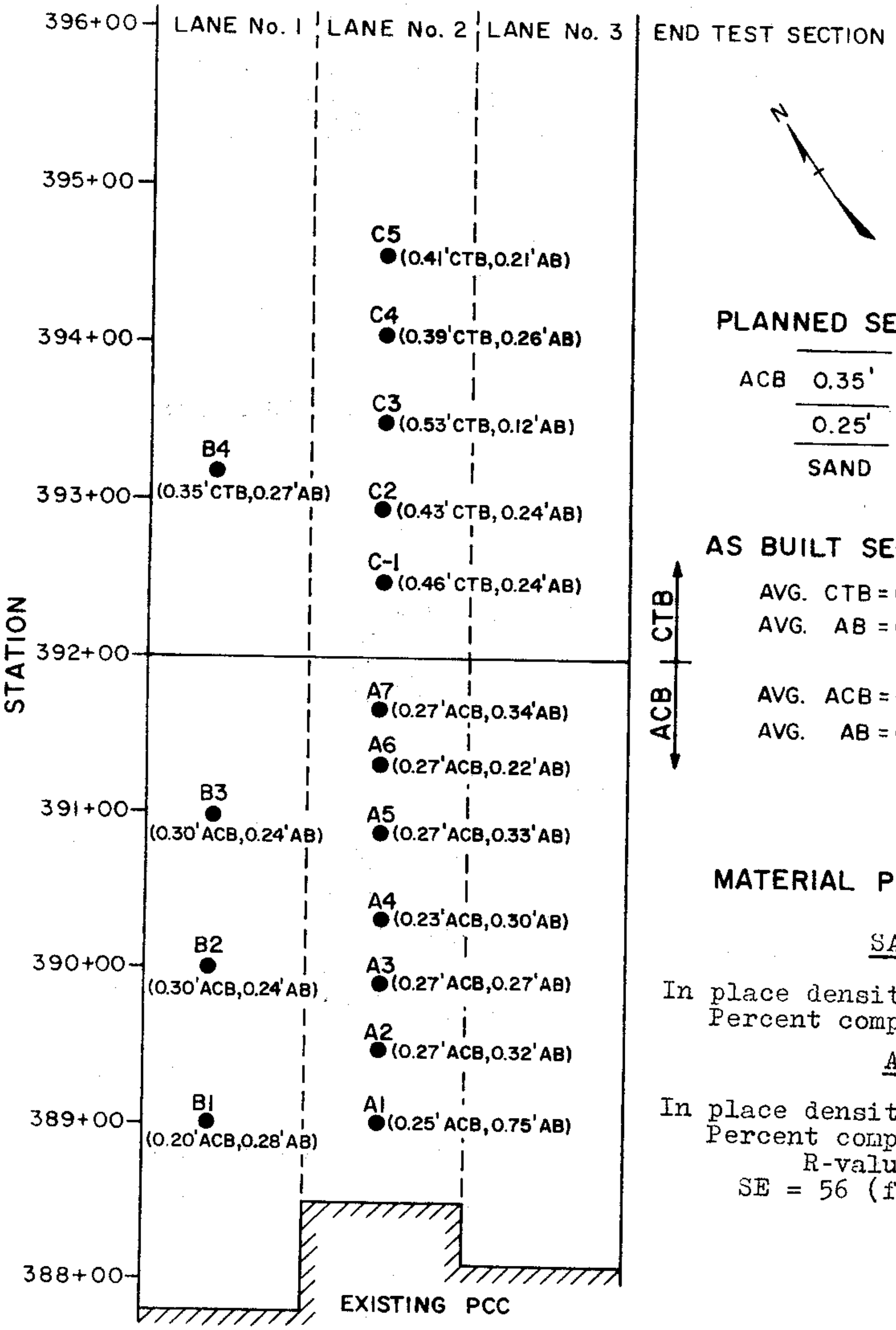
LABORATORY TESTS OF ACB AND CTB PLACED UNDER PCC PAVEMENT

| PROJECT | ACB | | | | CTB |
|---|---|---|---|---|---|
| | Abson Recovery Tests | | | Surface Abrasion Test | Surface Abrasion Test |
| | Pen. at 77°F | Softening Point | Ductility at 77°F | | |
| 06-Mad-99-18.5/22.5 (PCC placed over ACB in 1959) (PCC placed over CTB in 1951) | 5 | 167°F | 0 cm | 1.5 gm | 8.2 gm |
| 06-Tul-99-41.2/48.3 (PCC placed over ACB in 1971) (PCC placed over CTB in 1951) | 3 | 178°F | 1 cm | 1.7 gm | 1.9 gm |
| 05-Mon-1-R80.9/R85.0 (PCC placed over ACB in 1973) (PCC placed over CTB in 1973) | 52 | 128°F | 100+ cm | 0.6 gm | 25.7 gm |

Note: 1 in. = 25.4 mm
1 ft = 0.305 m

Figure 1

# ACB AND CTB IN-SITU TEST AREAS ON PROJECT 05- Mon - 1




NOTE 1 in. = 25.4 mm
1 ft = 0.305 m

**PLANNED SECTION**

ACB 0.35' CTB
0.25' AB
SAND

**AS BUILT SECTIONS**

AVG. CTB = 0.44'
AVG. AB = 0.21'

AVG. ACB = 0.26'
AVG. AB = 0.36'

**MATERIAL PROPERTIES**

SAND

In place density = 2.07 gm/cm$^3$
Percent compaction = 99

AB

In place density = 2.40 gm/cm$^3$
Percent compaction = 95
R-value = 83
SE = 56 (fine agg.)

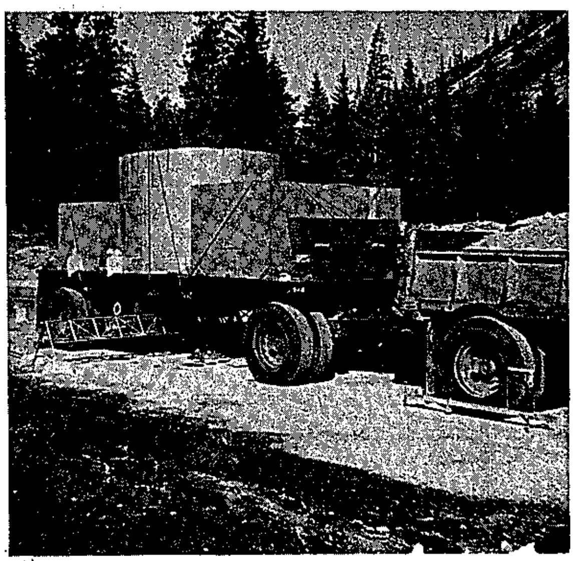


Fig. 2 CORPS OF ENGINEERS TEST TRAILER

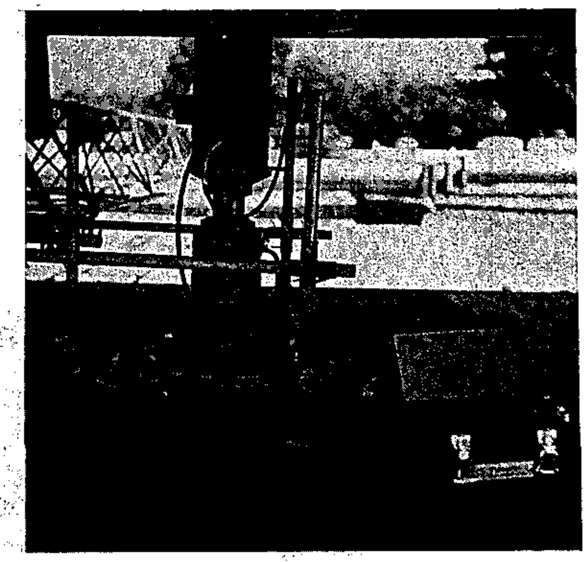
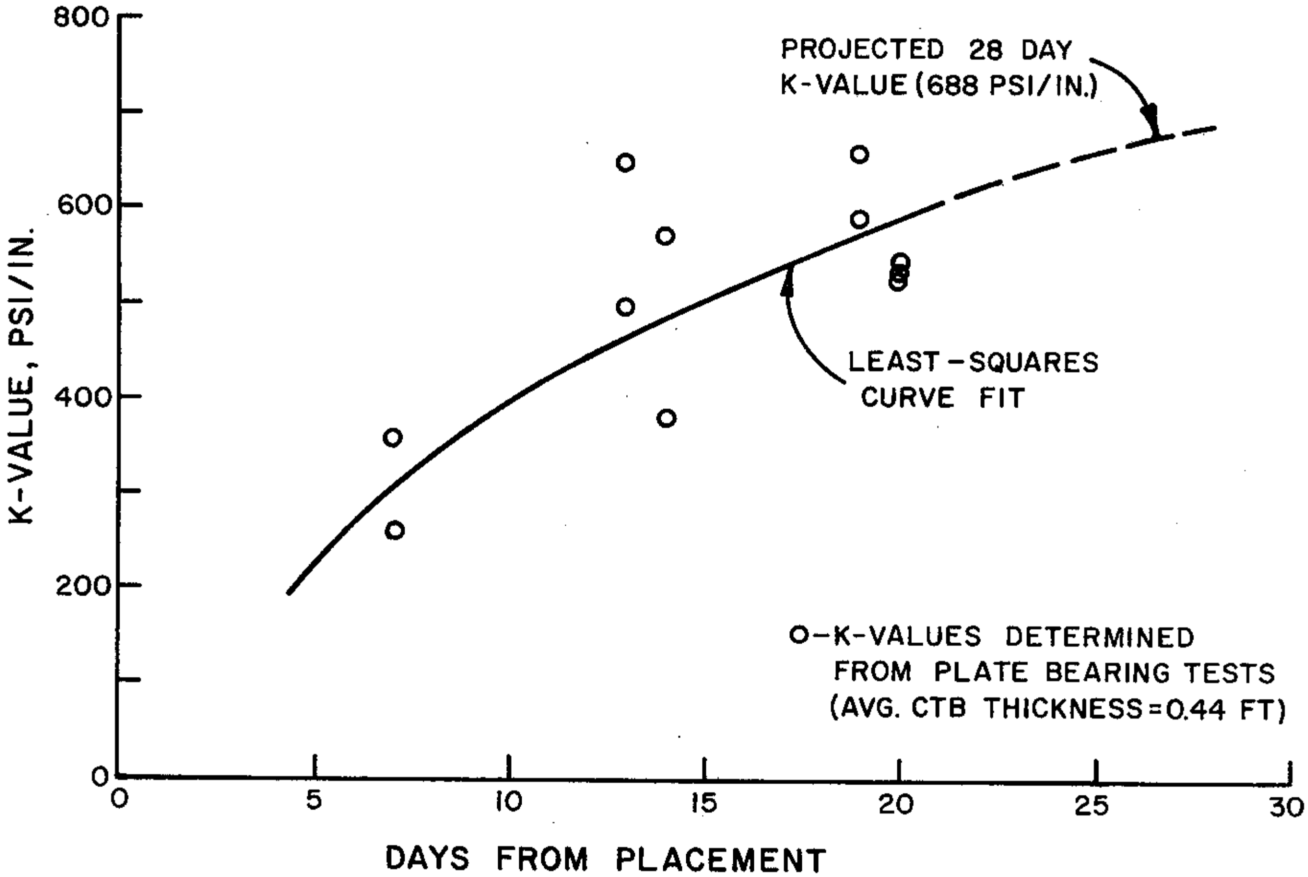


Fig. 3 PLATE BEARING TEST ARRANGEMENT

Figure 4

# K-VALUES FOR CTB PLACED ON PROJECT 05-MON-1




NOTE: 1 in. = 25.4 mm
1 ft = 0.305 m
1 psi / in. = 271 k Pa/m

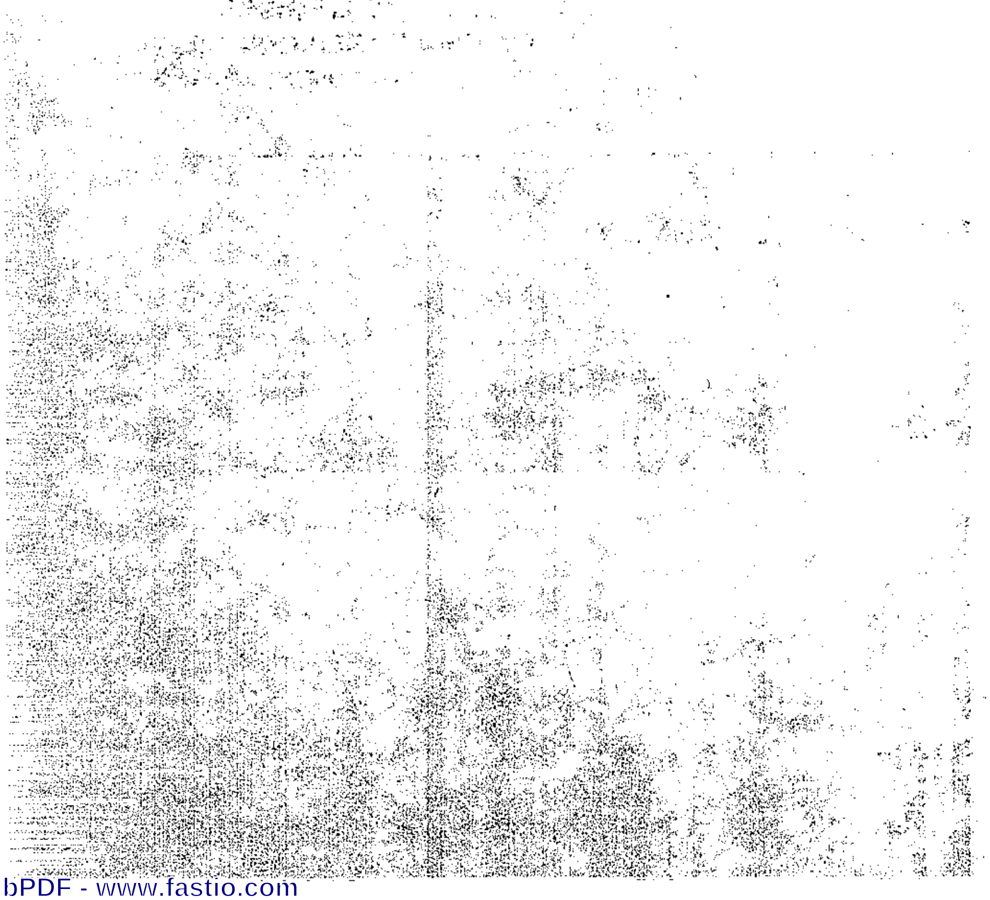
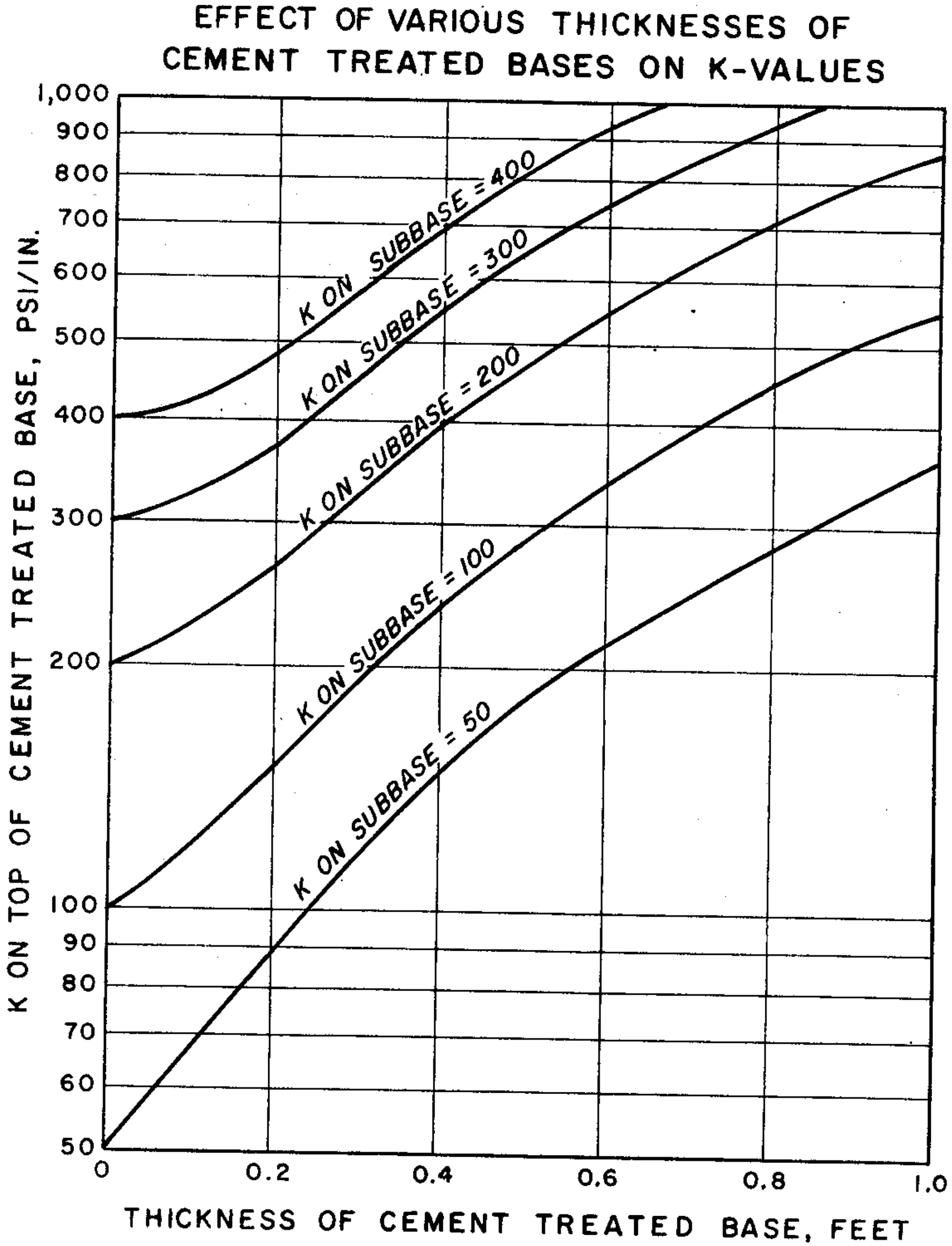


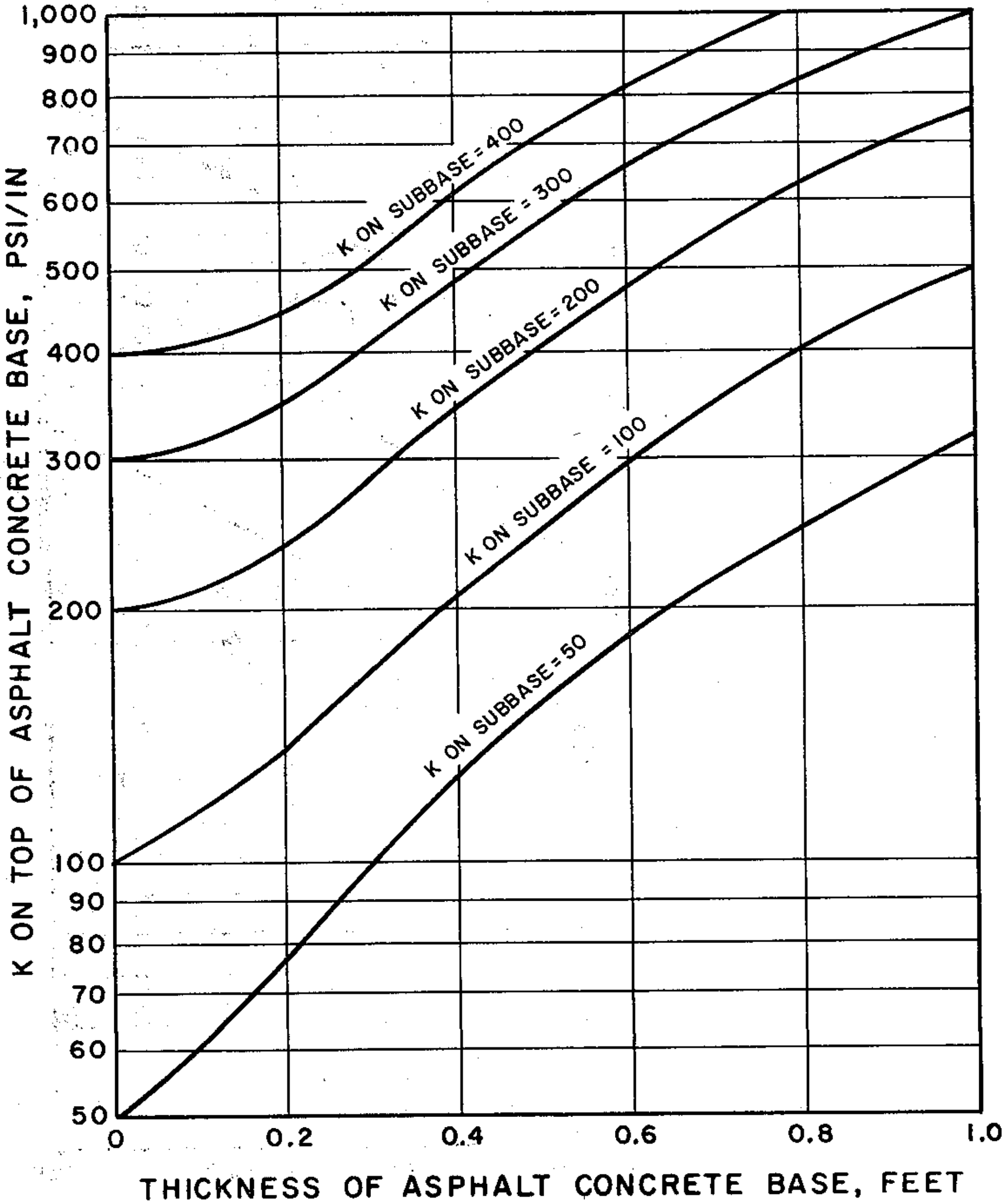
Figure 5




NOTE: 1 in. = 25.4 mm
1 ft = 0.305 m
1 psi/in. = 271 k Pa/m

Figure 6

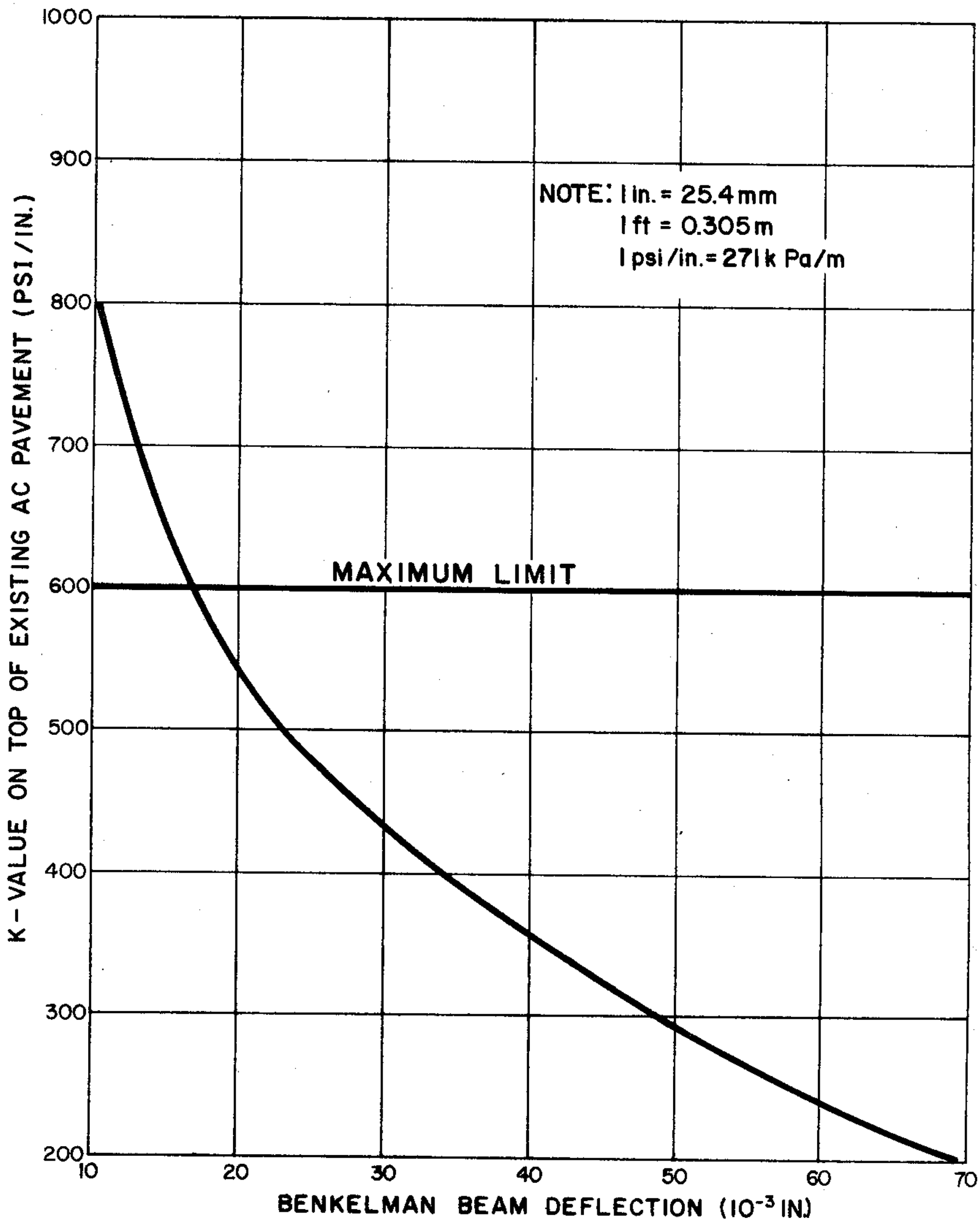
EFFECT OF VARIOUS THICKNESSES OF ASPHALT CONCRETE BASES ON K-VALUES

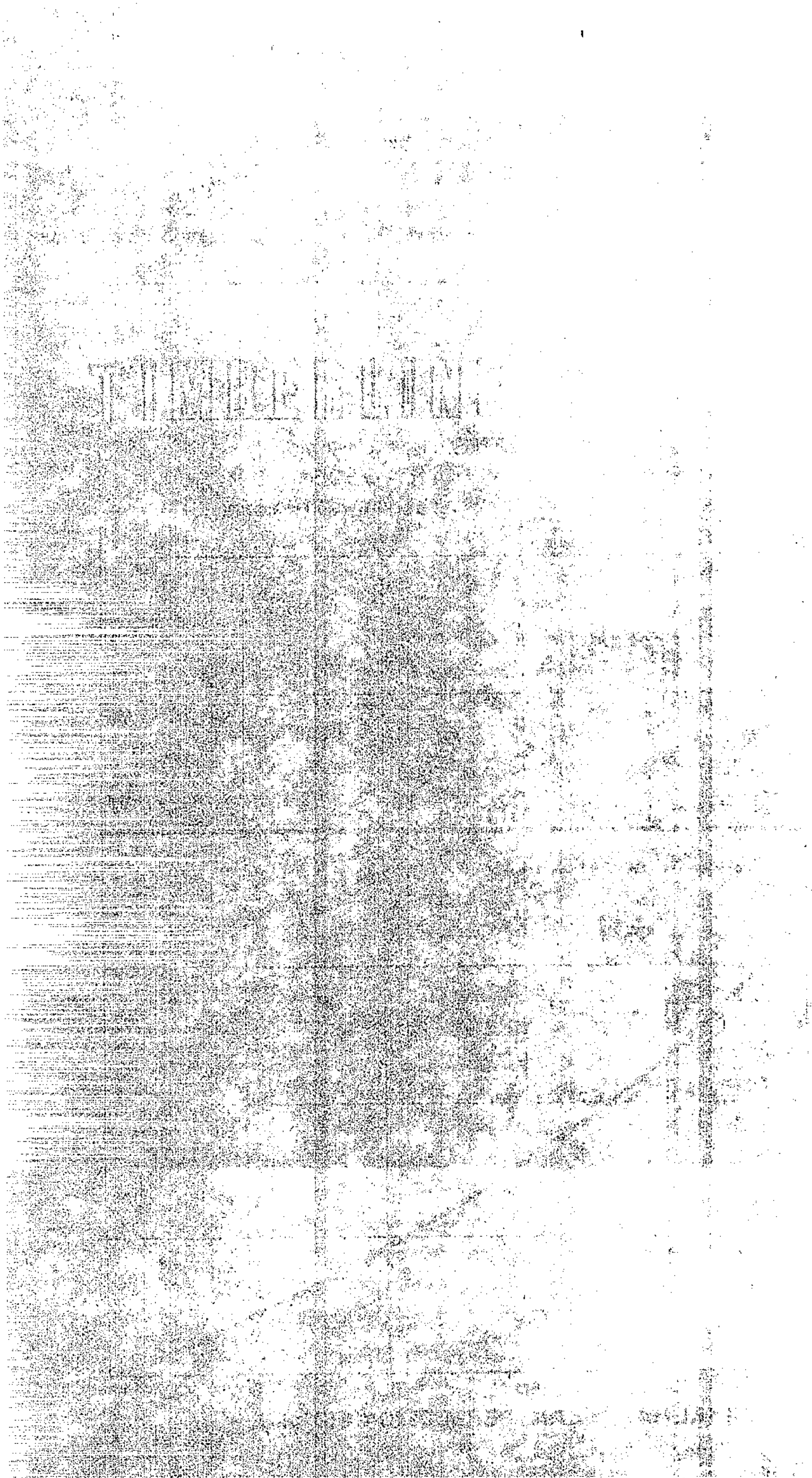


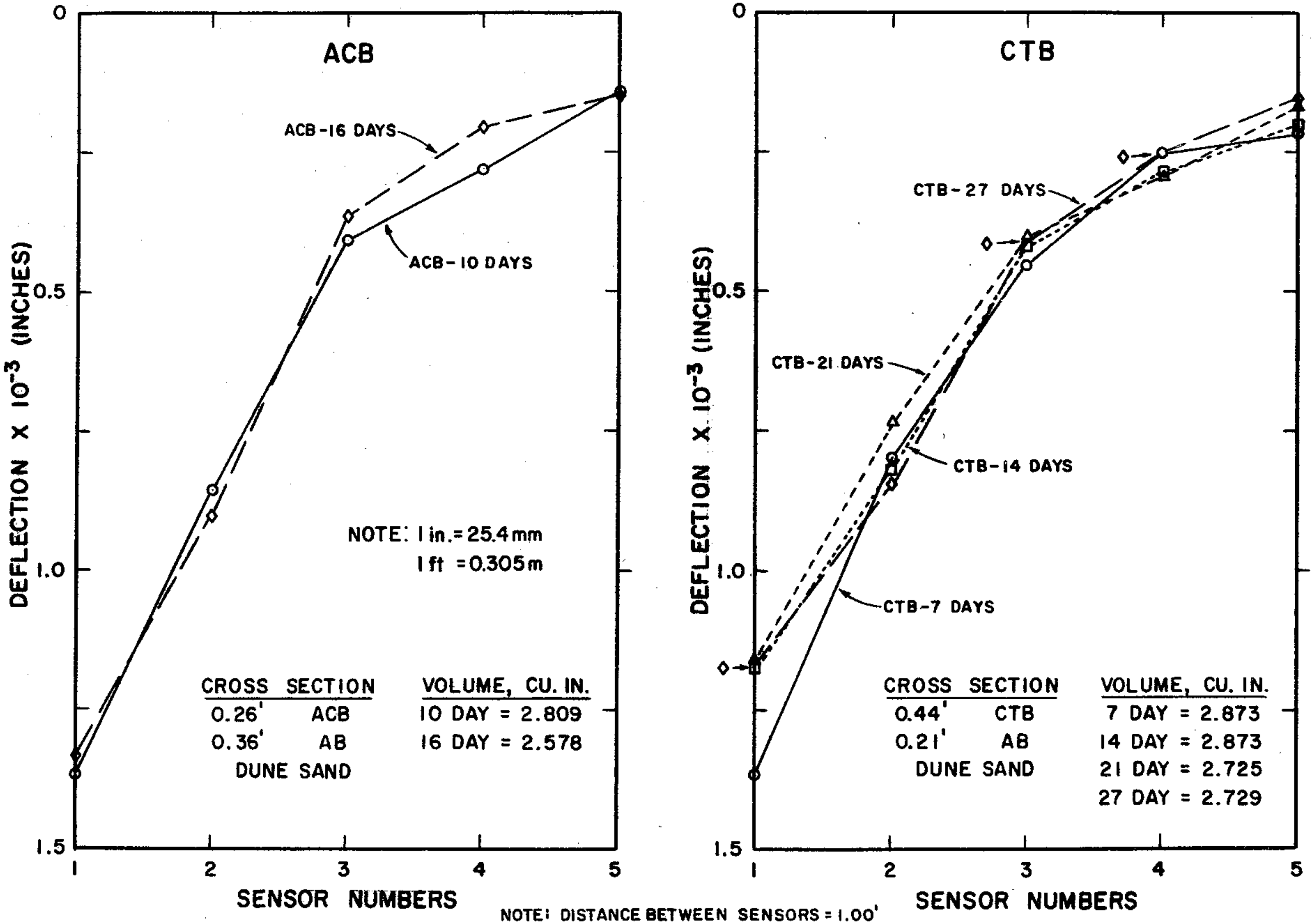

NOTE: 1 in. = 25.4 mm
1 ft = 0.305 m
1 psi / in. = 271 k Pa/m

Figure 7

# K-VALUE VS. DEFLECTION FOR AC PAVEMENT








NOTE: DISTANCE BETWEEN SENSORS = 1.00'
SENSOR NO.1 AT CENTER OF LOADING

Fig. 8 DYNAFLECT DEFLECTIONS
PROJECT 05-Mon-1